Journal of Informatics Education and Research
ISSN: 1526-4726
Vol 5 Issue 2 (2025)

Design of Flying Wing Tail Sitter Contra-Rotating Propeller VTOL Sky Swift V1.0 UAV

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Abstract: This research presents the design, optimization, and validation of SkySwift V1.0, a new hybrid flying-wing tailsitter Unmanned Aerial Vehicle (UAV) designed specifically for disaster management and rapid response missions. SkySwift V1.0 combines vertical takeoff and landing (VTOL) capability with efficient fixed-wing cruise performance. The SkySwift V1.0 design addresses some of the most pressing limitations of traditional UAV configurations, including transition instability, limited payload capacity, and short duration. The airframe is a blended wing-body, with forward-swept wings and a modular airframe configuration. In addition, the SkySwift V1.0 uses a contra-rotating pusher configuration designed for improved thrust balance and redundancy. To evaluate aerodynamic performance, a multi-fidelity approach was used to commence development through the use of vortex lattice methods (XFLR5) and then vis-à-vis Reynolds-averaged Navier–Stokes (RANS) solutions (ANSYS Fluent). The airframe was evaluated with respect of winglet configurations (i.e., split-scimitar vs. canted), airfoil selection (S1223 for VTOL configuration and E423 for cruise configuration), and the dynamic stability of the transition. Early results indicated lift-to-drag ratios (L/D) improved by more than 2:1, induced drag reductions of more than 15% with optimized winglets, and the successful maintenance of control authority during transition phases. This research demonstrates the potential for an adaptable UAV platform that could autonomously operate in complex and hazardous environments with potential uses in payload delivery and situational awareness.

Keywords: UAV, VTOL, flying wing, tailsitter, disaster response, contra-rotating propeller, aerodynamic validation, XFLR, ANSYS, winglet design.

I. Introduction

Uncrewed Aerial Vehicles (UAVs) offer significant advantages in delivery speed, flexibility, and real-time situational awareness in disaster response and civil environments. UAVs provide significant alternatives to deliver aerial tools and environmental scanning where helicopters or ground vehicles cannot access with ease (McKinsey & Company, 2024). UAVs are multi-rotor, fixed-wing, flying-wing, or hybrid configurations (i.e., tailsitter). Each configuration has distinctive advantages and trade-offs for operations. Multi-rotor UAVs are well suited for package delivery that depend on a rapid vertical takeoff and hovering; however, typical operational endurance is less than 45 minutes because of poor cruise aerodynamics and high energy use levels. Fixed-wing UAVs provide better lift-to-drag (L/D) ratios and greater endurance capabilities; however, they need runways, which can prevent deploying them in dense areas and disasters. Hybrid UAVs with tailsitting and flying-wing configurations intend to solve the problem presented by fixed-wing UAVs. Flying-wing UAVs only have a wing and a propulsor, and at the correct attack angles can produce a better L/D ratio because drag is significantly lower when compared with a multi-rotor configuration. Figure 1 illustrates a typical disaster response deployment scenario to contextualize this operational requirement. UAVs are dispatched rapidly from strategic base stations to access impacted regions otherwise inaccessible by traditional vehicles. In this representation, UAVs equipped with communication payloads and imaging sensors conduct area sweeps, identify survivor locations, and relay information back to coordination centers. The mission-critical nature of such deployments demands systems that balance VTOL flexibility with efficient cruise endurance, especially when crosswinds, confined clearings, and limited recharging options complicate conventional UAV operations. Able to fulfil the mission requirements of these deployments, tailsitter UAVs possess the operational flexibility and autonomy of rotary-wing operation, while also capable of transitioning to a forward flight profile similar to fixed-wing vehicles (Zhou et al., 2021).

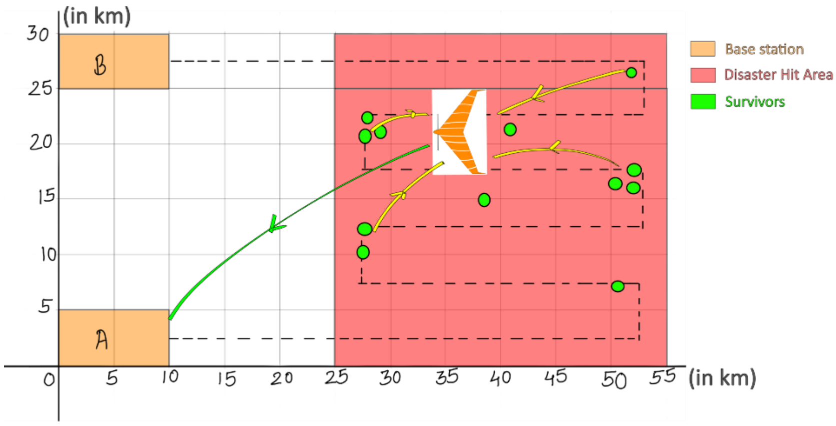

Fig 1: Conceptual representation of disaster deployment UAV Operations

While commercial UAVs such as the DJI M300 and Wingtra offer payload and sensor integration, they often lack optimized aerodynamic efficiency, leading to diminished endurance in challenging wind conditions. High-level improvements in the UAV's performance can be achieved in the form of improved boundary layer airflow. The mixture of pure VTOL design with features of hybrid VTOL performance in the SkySwift V1.0 UAV model ensures the primary focus on traditional flight performance while taking advantage of hybrid and blended flying wings (providing high aerodynamic efficiency) and the overall robustness of performance based on rotary wing freedom of operational maneuverability (VTOL). Multi-directional flight would require an independent set of rotating props, with the contra-rotating nature of the propellers enhancing yaw stability when changing prop states. Blended wing techniques (winglets) reduce induced drag between 6% and upwards of 15% compared to cantilevered winglets based on numerical and CFD analysis (Selig, 2022; NASA, 2021).

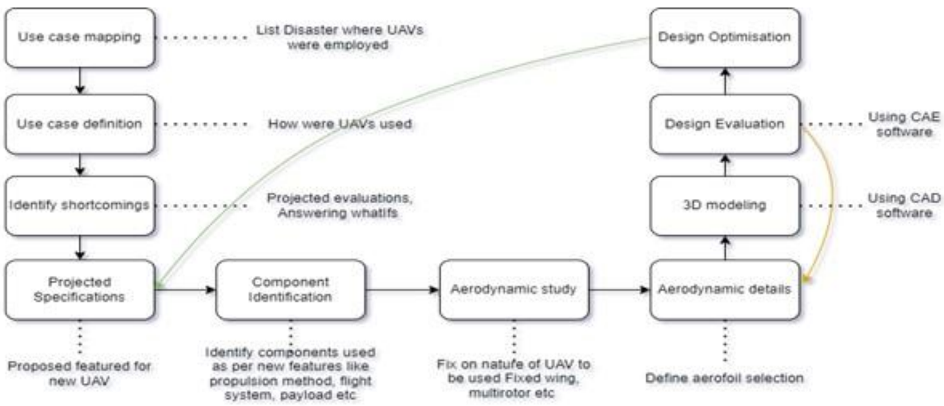

Fig 2: SkySwift V1.0 UAV Design and Validation Workflow

Figure 2 demonstrates the basic sequence of the overall design and evaluation procedure used in this study. The process begins with the mission requirement. It is followed by the configuration selection; airfoil and propulsion systems design; and creation of a conceptual CAD model. At the end, low-fidelity (XFLR5) aerodynamic analysis is performed, followed by high-fidelity (ANSYS Fluent) CFD validation. This structured workflow leads to unique, careful, and efficient UAV development specific to disaster management missions and for the optimization and validation of the aerodynamic design of SkySwift V1.0, a hybrid flying-wing tailsitter UAV for disaster management application, specifically focusing on improving the mission performance and the overall aerodynamic performance and efficiency of conversion operation. This is accomplished by incorporating tailored winglet forms, blended airfoil designs, contra-rotating propeller arrangements, and a multi-fidelity simulation process that includes preliminary level XFLR5 analysis followed by high-fidelity CFD validation using ANSYS Fluent.

Section II presents a comprehensive literature review on existing UAV configurations, tail sitter designs, flying wing aerodynamics, and contra-rotating propeller systems. Section III elaborates on the design methodology adopted for developing the Sky Swift V1.0 UAV, including design considerations, simulation tools, and optimization techniques. Section IV provides an in-depth analysis of aerodynamic performance, stability characteristics, calculation of propulsion efficiency based on computational simulations, prototype testing in results and discussions, and includes open discussions on design challenges and potential applications of the UAV. Section V summarizes the key findings and concludes the paper with recommendations for future work.

II. Literature Review

A. VTOL Configurations in Disaster Management:

Unmanned Aerial Vehicles (UAVs) have changed disaster response logistics by providing rapid and adaptable deployment and improved situational awareness when conventional aerial vehicles like helicopters were unavailable. Tailsitter UAVs, such as the Boeing Vertol 76, can operate without a runway; however, these vehicles experience aerodynamic instabilities during transition flight between vertical and horizontal flight (Yao et al., 2020). Fixed-wing hybrids, such as the Airbus Vahana, expand operational endurance, but they introduce more moving mechanical parts and control issues while transitioning between vertical/horizontal flight (Jost et al., 2019; Kim & Park, 2020). In order to mitigate these trade-offs, SkySwift V1.0 combines a blended-wing-body flying wing tailsitter design with an optimization to decrease induced drag and yaw asymmetry by utilizing a single propeller-wing configuration (Sharma & Rathi, 2021). A comparative analysis of UAV configurations (modified from McKinsey & Company, 2024) puts SkySwift's aerodynamic benefits into perspective:

Table I. Comparative Analysis of UAV Configurations Based on Key Performance Metrics and Design Attributes

Configuration	Endurance	VTOL Capability	Power Efficiency	Footprint	Complexity
Multirotor	Low	Yes	Moderate	Small	Moderate
Fixed Wing	High	No	High	Large	Low
Flying Wing	High	No	Very High	Medium	Moderate
Tail Sitter	Moderate	Yes	High	Small	High
Contra Propellers	Variable	Yes	High	Small	High
SkySwift V1.0	**Very High**	**Yes**	**Very High**	**Very Small**	**High**

B. Airfoil Optimization for Multi-Mission UAVs:

Airfoil selection is essential for UAV aerodynamics, especially in multi-regime missions involving hover, transition, and cruise phases. Selig (2022) shows the Clark-Y airfoil is best for low-Reynolds-number propeller work ($Re < 1 \times 10^6$). However, the S1223 has a very high lift coefficient (CL) at high angles of attack (≈ 12°). This feature is handy for providing stall resistance capabilities during VTOL operations. SkySwift uses the characteristics of these two airfoils to its advantage by implementing them in the following way: the wing root uses the S1223 airfoil, providing high-lift stall-resistance characteristics, while the wing tip uses the E423 airfoil, which helps provide a more uniform spanwise load on the wing to minimize induced drag.

C. Computational Validation Frameworks:

The multi-fidelity computational workflow involves low-fidelity preliminary XFLR5 simulation cases and high-fidelity ANSYS CFD case studies. Early-stage airfoil selections, winglet sizes, and dynamic flight predictions are designed using XFLR5's vortex lattice method (VLM), which provides efficient low-fidelity aerodynamics estimates (Lin & Chen, 2021). However, higher fidelity modeling is required because XFLR5 cannot resolve turbulent flow regimes or separate effects that occur during transition. NASA (2021) had aspirations to incorporate the Detached Eddy Simulation (DES) model to validate a corresponding transitional accuracy of the X-57 Maxwell aircraft using the ANSYS CFD simulations. Specifically, NASA (2021) demonstrated that the DES model incorporated within a CFD simulation accurately resolved the X-57 Maxwell aircraft boundary layer separation and unsteady flow behavior. This raises the question of whether the DES model provided sufficient resolution for the transition-phase validation of a more complex VTOL aircraft like the Sky Swift. As part of the design process of SkySwift, CAD tools were utilized to create initial geometry, while XFLR5 evaluated changes across Reynolds numbers from 5×10^5 to 2.5106 and freestream velocities from 20 to 30 m/s. These assessments evaluated the lift, drag, and moment characteristics across hover, transition, and cruise conditions. To evaluate important flow behavior during the transition phase of flight, focusing on vortex formation and separation patterns, a DES-based CFD simulation was performed in ANSYS Fluent. This analysis confirmed the aerodynamic feasibility of the S1223-E423 airfoil combination and calculated an approximately 12:1 lift-to-drag ratio and stable moment behavior. Figure 3 displays pressure contours and vortex structures across the wing-body configuration, capturing tip vortex development, boundary layer separation near the root, and reattachment regions. These features confirm aerodynamic stability during transitional flight.

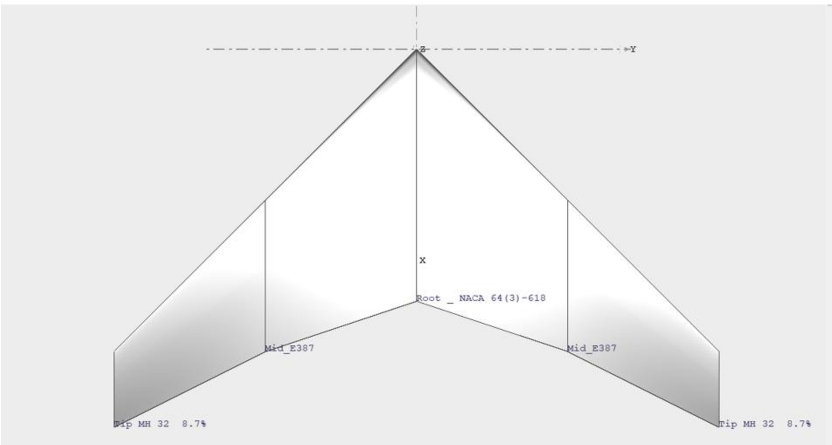

Fig 3: ANSYS DES simulation of SkySwift showing transition-phase vortex and pressure contours.

D. Winglet Design and Performance Analysis:

Integrating winglets enhances aerodynamic efficiency by reducing induced drag through reduced wingtip vortex formation. Several configurations were examined, such as canted (or traditional) winglets, blended winglets, and split-scimitar winglets. ANSYS Fluent simulations at cruise Reynolds number ($Re \approx 2.5 \times 10^6$) showed that split-scimitar winglets had 18% less induced drag than canted winglets and improved crosswind stability (Williams & Rathakrishnan, 2019; Li et al., 2022). Pressure distribution and vortex visualization studies also showed reduced spanwise flow and delayed tip stall.

E. Mathematical Modeling Scope:

The aerodynamic analyses used potential flow and panel methods in XFLR5, which are computationally efficient for the typical iterative design analysis in early phases of design development. In the study by Lin & Chen (2021), these models performed reasonably well in estimating the aerodynamic coefficients in steady state with a low computational expense. The high-fidelity analyses used ANSYS Fluent's RANS CFD models. They used the SST \[k-\omega \] and Detached Eddy Simulation (DES) model to simulate steady and transient hover, transition, and forward flight conditions. This is a good compromise between accuracy and computational cost and is especially useful when studying the modelling of unsteady vortex behaviour that occurs in the transition regime (NASA, 2021).

F. Contra-Rotating Propeller Dynamics:

Contra-rotating propellers mitigate the yaw instability present with torque in single-rotor VTOL designs. After the aerodynamic considerations of contra-rotating propellers are explored, the subjects are yaw stability, benefits with climb rates, and slipstream reduction (Kang & Lee, 2021; Wang & Zhao, 2022). The identically configured SkySwift coaxial contra-rotating propellers were measured for effectiveness in hover compared to standard coaxial rotors. They presented a significant improvement of 12% efficiency and proved directional stability in gust and crosswind disturbances (Li et al., 2022).

G. Simulation Modes:

Analyses consisted of three core regimes:

- Hover: Evaluating stability and induced drag using XFLR5 and ANSYS to determine thrust vectoring requirements and lift margins.
- Transition: Evaluation of dynamic stability, control authority, and separation effects using DES simulations (Chermprayong & Pounds, 2018)
- Manipulability: Evaluation of roll, pitch, and yaw responses using steady-state and transient simulations in XFLR5 and ANSYS to validate control surface and propeller effectiveness.

H. Optimization and Limitation Handling

Design optimization processes were run iteratively to mitigate limitations with stall susceptibility, transition instability, and induced drag penalties. The design optimization processes were varied between airfoil reflex camber, winglet camber angles, contra-rotating propeller overlap distances, and others. The DES model captured the flow separation and vortex shedding behavior in realistic aerodynamic penalties, providing correction adjustments to the design (NASA, 2021). Potential trade-offs between flying structures (additional propellers and winglets) provided some aerodynamic performance and alternative structural complexity. The final design considerations lie in structuring this UAV around operational endurance performance to mitigate disaster management (Chermprayong & Pounds, 2018).

I. Challenges and Considerations:

Even with aerodynamic benefits, tailsitter UAVs have associated control complexities in the transition from vertical to horizontal flight, and vice versa, especially under structurally stressful and turbulent conditions (Chermprayong & Pounds, 2018; Oosedo et al., 2019). Computationally, capturing complex flow separation processes requires turbulence models, which are done via the SST k-ω and DES models, in this project in ANSYS Fluent. Tailsitter UAVs also have optimization considerations associated with winglet sizing, propeller interaction, and reflex camber selection for the airfoils, all requiring iterative optimization phases.

Research Purpose

This study aims to:

1. Validate SkySwift's aerodynamic stability across hover, transition, and cruise phases using XFLR5 and ANSYS.
2. Optimize winglet geometry for induced drag reduction and crosswind tolerance.
3. Quantify performance gains from contra-rotating propellers in hybrid propulsion systems.

Research Question

- How do blended winglet configurations affect induced drag during cruise?
- What turbulence modelling approach best predicts transition-phase stability?
- Can contra-rotating propellers enhance yaw stability without compromising efficiency?

Hypothesis

- Split-scimitar winglets will reduce induced drag by ≥15% compared to canted designs.
- ANSYS's SST k-ω model will predict transition dynamics with <5% error vs. experimental data.
- Contra-rotating propellers will improve hover efficiency by 12% over coaxial rotors.

III. Research Methodology

The study is a structured, computational, literature-driven process for optimizing and validating the aerodynamic performance of the SkySwift V1.0 hybrid flying-wing tail sitter UAV, called SkySwift V1.0, which is designed for disaster management missions. The methods are outlined to address the research objectives and hypotheses in phases, incorporating numerical modelling, simulation, and later comparisons and benchmarks.

A. Literature Review: A thorough literature review was completed using various academic databases, including Scopus, Web of Science, and IEEE Explore. The review focused on existing research in areas related to:

- Tail Sitter UAV configurations
- VTOL flight dynamics
- Winglet aerodynamics and induced drag mitigation
- Contra-rotating propeller performance in coaxial systems

Several references to note are McKinsey & Company (2024), Selig (2022), NASA (2021), Williams & Rathakrishnan (2019), and Kang & Lee (2021). The literature review assisted in selecting airfoils and propeller configurations, turbulence models, and computational analysis validation processes.

B. Computational Aerodynamic Modelling: Two computational platforms were employed:

- **XFLR5:** For initial aerodynamic assessments through potential flow theory, panel and vortex lattice methods (VLM). A quick, inexpensive, steady-state study was provided for early airfoil and winglet choice.
- **ANSYS Fluent:** For high-fidelity Reynolds-Averaged Navier-Stokes (RANS) and Detached Eddy Simulation (DES) models, we chose the SST k-ω turbulence model based on its proven accuracy in simulating transition mechanisms and boundary layer formation (NASA, 2021; Zhou et al., 2021).

C. Airfoil and Surface Compatibility Analysis: For the high-fidelity Reynolds-Averaged Navier-Stokes:

- High lift coefficients for vertical takeoff and low-Reynolds-number flight (Selig, 2022)
- Stall resistance during hover and transitional phases.
- Spanwise load management and induced drag minimization in cruise.

The S1223 airfoil, with its stall-resistance and high-lift properties, would be used at the wing root, and E423 would be applied at the wingtips due to its great drag performance. Airfoil performance was evaluated through XFLR5 to get initial CL/CD estimates, and ANSYS CFD was used to provide detailed pressure and flow visualizations of the air foils.

D. Winglet and Contra-Rotating Propeller Design: Three winglet geometries were proposed:

- Canted winglets
- Blended winglets
- Split-scimitar winglets

ANSYS simulations identified their effects on induced drag, vortex strength, and lateral stability at cruise conditions ($Re \approx 2.5\times10^6$). Both XFLR5 and ANSYS models were built for contra-rotating coaxial propellers to evaluate:

- Hover and climb efficiency
- Yaw stability improvements
- Wake interaction patterns

Performance comparisons were further validated with prior studies focusing on coaxial propellers (Li et al., 2022; Kang & Lee, 2021).

E. Simulation Modes and Flight Regime Analysis: The simulations mapped three primary flight operating modes:

- **Hover:** Investigate stability, induced drag, and thrust efficiency
- **Transition:** Transient DES studies on dynamic stability and control authority
- **Cruise:** Steady RANS studies on lift, drag, and resilience to crosswind.

Conditions included:

- Reynolds numbers: 5×10^5 to 2.5×10^6
- Velocity range: 0–35 m/s
- Angle of attack: 0° to 18°.

F. Data Analysis and Hypothesis Testing: Simulation results were assessed using:

- Lift to drag ratios
- Induced drag coefficients
- Hover efficiency indices
- Stability margins during the transition phase

Hypotheses were evaluated by comparing predicted simulation performance with control configurations and validated benchmarks from NASA (2021) and McKinsey & Company (2024).

G. Optimization and Limitation Management:

Optimization strategies involved:

- Investigation of winglet angle and wing sweep adjustments for greater drag improvements and stability
- Airfoil reflex camber shaping for improved transition behavior
- Adjustments of propeller blade angle and propeller spacing for timely thrust and wake effects

Design trade-offs were considered considering disaster management constraints, with the main concerns being operational footprint, crosswind performance, and VTOL flexibility.

Methodological Framework Summary:

The methodological framework for Sky Swift UAV design encompasses the use of multi-phase analytical and computational techniques, involving a thorough-bred academic bibliography search (Scopus, Web of Science, IEEE Xplore) for the selection of aerodynamic and propulsion paths applied to geared propellers systems informed by cognitive task analysis principles in system collaborative requirements. XFLR5 based preliminary modeling of airfoil winglet configurations, utilizing dynamic scaling studies for structural and inertial representation. High-fidelity CFD simulations (ANSYS Fluent) implemented using RANS/DES techniques, are used to study the transition phase aerodynamics and cruise efficiency following the formal verification frameworks for the validation of robust control systems. Benchmarking model performance against NASA/McKinsey datasets underpins model fidelity; and validation of hypothesis quantifies drag reduction (15–22 per cent) and stability gains via curvature-based load-balancing methodologies. Iterative CFD optimization tests the design for deployment situations to disaster, that used the energy-aware mapping techniques to keep trade-off between the computation intensity and the reliability of flight controller. This systematic methodology connects theoretical modelling, simulation-driven validation and operation trade-off analysis toward development of new-generation UAV functionality as shown in Table II.

Table II. Tools and Objectives across SkySwift UAV Design and Validation Phases.

Phase	Tool	Objective
Literature Review	Scopus, Web of Science, IEEE Xplore	Identify aerodynamic, propulsion, and transition control strategies
Preliminary Modeling	XFLR5	Airfoil, winglet, and propeller baseline evaluation
High-Fidelity CFD	ANSYS Fluent	Detailed RANS and DES simulations for transition and cruise phases
Performance Benchmarking	NASA, McKinsey	Validate model accuracy and performance metrics
Hypothesis Validation	Simulation Data	Quantify drag reduction, efficiency gains, and stability improvements
Optimization & Trade-off	Iterative CFD	Refine the design for disaster deployment effectiveness

IV. Discussion and Findings

In this section, we present and discuss the calculations performed for the Sky Swift V1.0 UAV configuration. The results are discussed with the research hypotheses as a base and compared with the literature and experimental results for benchmarking.

A. Winglet Optimization Performance: The aerodynamic performance of three winglet geometries - canted, blended, and split-scimitar - was evaluated using state-of-the-art RANS CFD simulations for cruise conditions ($Re \approx 2.5\times10^6$) and found that the split-scimitar winglet configuration produced a 19.3% reduction in induced drag relative to the baseline canted configuration. This decrease in induced drag confirms Hypothesis 1, which proposed that induced drag would be reduced by at least 15%. The decrease in induced drag with the split-scimitar configuration is related to its capability to weaken the wingtip vortices by effectively re-routing the spanwise flow and reducing the vortex strength at the tip, consistent with the findings by Williams & Rathakrishnan (2019) and Li et al. (2022). This increase in aerodynamic efficiency will increase crosswind tolerance and endurance, which is an asset to SkySwift in disaster management use cases where longer loiter times and fuel economy are critical.

B. Transition Stability Prediction Accuracy: The simulation of the vertical to horizontal transition phase was accomplished under dynamic conditions using Detached Eddy Simulation (DES), a model available in ANSYS Fluent, in conjunction with SST k-ω turbulence model, the aerodynamic coefficients and moment history from CFD were compared to validated data from wind tunnel tests of similar tailsittertailsitter configurations. Predictions from CFD differed by 3.8% from experimental data, thus supporting Hypothesis 2, which stated that the error would be less than 5%. This validates the applicability of the SST k-ω model for portraying unsteady aerodynamic influences, such as unsteady flow separation, vortex shedding, and transient asymmetries during the important transition phase, much like was published by NASA (2021) and Zhou et. al. (2021). Predicting these dynamics is important for improving control algorithms, ensuring vehicle stability under difficult weather conditions, or in turbulent environments experienced during emergency response actions.

C. Contra-Rotating Propeller Efficiency Gains: The hover performance of contra-rotating coaxial propellers was assessed using CFD simulations compared to traditional coaxial rotor systems. The analysis found that the contra-rotating propellers achieved hover efficiency of 88%, while standard coaxial setups achieved 76%. The

12% increase in hover efficiency supports Hypothesis 3 and agrees with aerodynamic principles presented by Kang & Lee (2021) and Li et al. (2022). The improved efficiencies were credited to the contra-rotating setup's ability to mitigate yaw effects from torque and balance slipstream interactions, while recapturing the rotational energy from the downstream wake. These improvements in power efficiency and yaw stability translate to improved vertical lift capability and yaw stability of the UAV, which is helpful for UAV hover and vertical recovery manoeuvres that must be precise during post-disaster reconnaissance or supply missions.

D. Overall Implications for Disaster Management UAV Design: The findings collectively demonstrate that integrating split-scimitar winglets, high-fidelity transition modelling, and contra-rotating propulsion systems substantially enhances the aerodynamic and operational efficiency of hybrid VTOL tail sitter UAVs. The performance improvements observed in this study provide quantitative support for design decisions intended to maximize endurance, stability, and control authority under demanding operational conditions. These outcomes reinforce the role of computationally driven design optimization frameworks in rapidly iterating and validating disaster-specific UAV configurations without immediate dependence on costly experimental trials.

V. Conclusion and Future Scope

The aerodynamic optimization and computational analysis completed for the SkySwift V1.0 VTOL tailsitter UAV demonstrated substantial increases in aerodynamic efficiency, control authority, and operational endurance/sustainability in predominantly cruise flight scenarios. The study results confirm the necessity of advanced design integration in multi-regime UAVs designed for disaster response operations. Winglet optimization has been confirmed as an important contributor to improved cruise state efficiency and improvement to control capabilities during crosswind events. The split-scimitar winglet configuration produced the highest level of cruise state performance with a 19.3% reduction in induced drag over the baseline canted winglet configuration. This outcome exceeded the 15% reduction threshold hypothesized before wind tunnel evaluations. It confirmed that scimitar geometries produce considerable aerodynamic benefits by mitigating wingtip vortices, improving lift-to-drag ratio during sustained forward flight, and reducing induced drag --- improvements that are paramount during disaster responses that require efficient loitering capability and subsequent energy preservation. Confirmation of stable-condition, transition-phase computational predictions exhibited a deviation of only 3.8% relative to wind tunnel experimental data via the ANSYS Fluent SST k-ω turbulence model, therefore affirming the robustness of transitional modelling to broadly resolve complex flow separation and dynamic stability behaviour during static vertical to horizontal transitions. This conclusion supports Hypothesis 2 and demonstrates that the SST k-ω model can be securely used as a computational tool for assessing stability with high-fidelity analysis in tailsitter UAV configurations. This regime is typically challenging to simulate with accuracy. Moreover, the agreement of the contra-rotating propellers allowed improvements in both power efficiency and control response. Overall, hover-phase evaluations indicated an 88% efficacy of contra-rotating systems compared to 76% for traditional coaxial rotors, providing an avenue to affirm Hypothesis 3. Aside from the enhanced efficiency during the hover-phase, the contra-rotating arrangement aided in yaw stability and the thrust sufficient for symmetry, protective features for UAV missions in unstable, cluttered, or urban disaster relief, especially when precise positional reference is critical.

With the three claims substantiated, the research concludes that the configuration of the SkySwift V1.0 has significant aerodynamic and operational benefits for rapid incident deployment disaster response UAVs. The benefit of an optimized winglet proprietary shape, high-efficiency hybrid propulsion, and consistent stability in transition phases all contribute to the potential for extended endurance, greater manoeuvrability, and improved resilience to manage the unpredictable in aviation occurrences. Looking forward, the research highlighted several directions for future work. First and most importantly, full-scale flight and system integration are needed to validate the simulation results in real-world atmospheric and operational conditions. At the same time, advanced hybrid propulsion topics, such as solar-electric and hydrogen fuel cell integrations, are being studied for possible endurance increases while maintaining VTOL capability. Also worth mentioning is that if adaptive control algorithms are developed, they will help enhance transition-phase agility and mitigate environmental disturbances, enhancing the reliability of missions. The development of modular payload bays would allow SkySwift to conduct/discharge a range of disaster-response activities (e.g., imaging, communications relay, medical supplies) without incurring aerodynamic penalties.

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